IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Beck *et al.*

Appl. No. 09/547,791

Filed: April 12, 2000

For: **System, Method, and Computer Program Product for Weather and Terrestrial Vegetation-Based Water Renovation and Management Forecasting**

Confirmation No. 5403

Art Unit: 3623

Examiner: Susanna M. Diaz

Atty. Docket: 1481.0170000

Statement of Facts in Support of the Reply to the Requirement for Information Under 37 C.F.R. § 1.105

Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

Dear Sir:

I, Frederic D. Fox, hereby declare:

1. I am making this statement of facts in support of the Reply to the Requirement for Information Under 37 C.F.R. § 1.105.

2. I am a co-inventor of the invention and the President of Planalytics, Inc. (hereinafter "Planalytics"), 1325 Morris Drive, Suite 201, Wayne, Pennsylvania 19087.

3. Planalytics provides services that assist clients in forecasting weather-driven changes in supply, demand, and prices for their products and services. The methodologies underlying some of Planalytics' services are disclosed in U.S. Patent Nos. 5,491,629; 5,521,813; 5,796,932; 5,832,456; 6,418,417; and 6,584,447.

4. I have firsthand knowledge of the events, facts, and assumptions relating to the development of the invention. These are summarized as follows:

   A. On or about June 30, 1999, the prospective co-inventors held a meeting in Kansas (hereinafter "the meeting") to discuss developing an inventive solution to a problem that had been observed with man-made reservoirs in which the water takes on an unpleasant odor and taste (hereinafter referred to as "the problem").

B. The prospective co-inventors at the meeting were affiliated with the University of Kansas, TerraMetrics, Inc., or Strategic Weather Services, Inc. (which has since changed its name to Planalytics, Inc.). The prospective co-inventors brought to the meeting expertise in the different disciplines from which the inventive solution was developed. Among those in attendance at the meeting were: Mr. Steven Beck, Mr. Sam Campbell, Prof. Frank deNoyelles, Prof. Stephen Egbert, Mr. David Penny, and Prof. Stephen Randtke.

C. Among the topics discussed at the meeting was a first *unpublished* document entitled "RESERVOIR MANAGEMENT AND RENOVATION *Addressing Problems in Multipurpose Reservoir Systems*" (hereinafter "the first unpublished document"). The first unpublished document was prepared by Prof. deNoyelles. Attached to the first unpublished document was a second *unpublished* document entitled "TERRESTRIAL GREENNESS RELATED TO WEATHER PARAMETERS AS INDICATORS OF RESERVOIR CONDITIONS" (hereinafter "the second unpublished document"). The second unpublished document was prepared by Prof. Egbert. The first and second unpublished documents were used by the prospective co-inventors to characterize the problem and to consider prospective solutions to be incorporated into the proposed invention. Copies of each of the first and second unpublished documents are attached hereto as Exhibit A.

D. The proposed inventive was based at least in part on an assessment that the costs to a government (or other responsible entity) of addressing the problem at the reservoir would be much less than the costs of trying to address it in a municipal water treatment system.

E. Patent counsel was present at the meeting and development of the invention was diligently pursued until at least the filing of the present patent application.

F. It is my understanding, based on information provided to me by patent counsel, that the "Background of the Invention" section of the present patent application was prepared from the information included in the first unpublished document attached hereto as Exhibit A.

G. Each of the co-inventors assigned his rights in the invention to Planalytics in March of 2000.

H. The present patent application was filed on April 12, 2000.

5. On or about June 10, 2005, I authorized patent counsel to contact the other co-inventors with regards to having them provide information in support of the Reply to the Requirement for Information Under 37 C.F.R. § 1.105 that issued on March 8, 2005. Responses from my co-inventors are attached as Exhibits B through F. Specifically:

Exhibit B is a Response to *Requirement for Information under 37 CFR § 1.105* received from Profs. deNoyelles and Egbert;

Exhibit C is a letter received from Mr. Beck;

Exhibit D is a letter received from Prof. Randtke;

Exhibit E is a letter received from Mr. Penny; and

Exhibit F is an e-mail message received from Mr. Campbell.

6. To the best of my knowledge, the underlying methodology is not based on a prior art methodology for performing weather and terrestrial-based analyses of bodies of water.

7. To the best of my knowledge, the named inventors invented the entire methodology described and claimed in the present patent application.

8. To the best of my knowledge, the novelty of the invention lies in the underlying methodology itself. Although the claims in the present patent application involve the automation of data gathering and calculations, to the best of my knowledge, the underlying methodologies were not previously known.

9. To the best of my knowledge, except for documents that may be referenced in the attached Exhibits or documents identified in various Information Disclosure Statements filed in the present patent application, no publications were relied upon to develop the disclosed subject matter that describes the invention.

10. To the best of my knowledge, no products or services currently incorporate the claimed subject matter or the underlying methodology of the invention.

I declare that all statements made herein of my own knowledge are true and that all statements made on information from review of the file history of the patent application are believed to be true, and further that these statements were made with the knowledge that willful false statements or the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the patent application or any patent issued thereon.

Respectfully submitted,

Frederic D. Fox

Date: 8-8-05

RESERVOIR MANAGEMENT AND RENOVATION

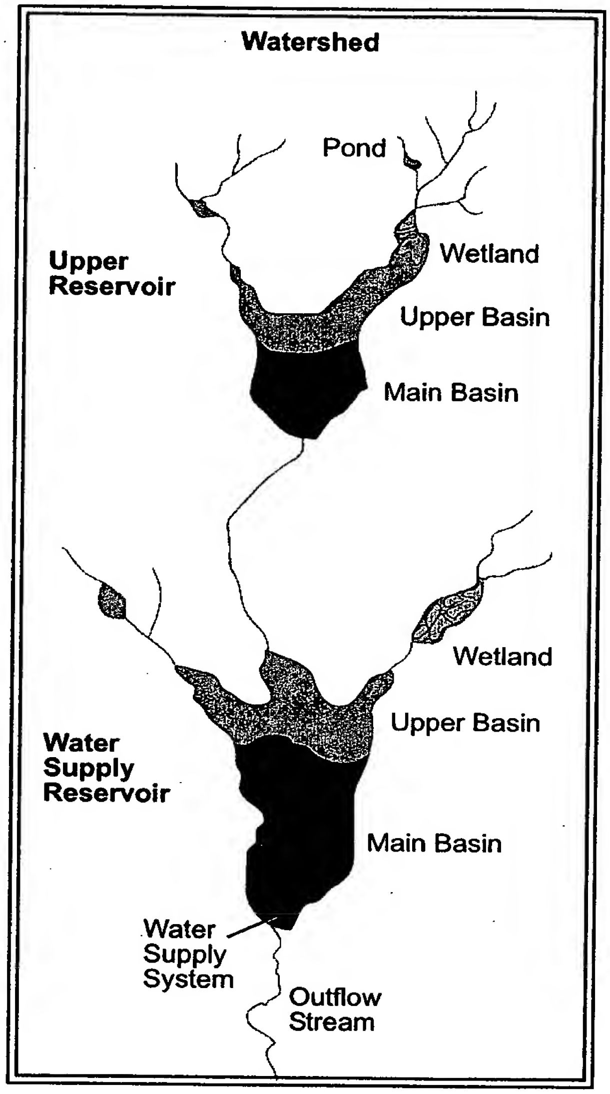
Addressing Problems in Multipurpose Reservoir Systems

Locating Sources
Identifying Causes
Evaluating Actions

Past and Present

- Ecosystem History
- Problem Description
- Problem Chronology
- Remote Sensing Analyses
- Weather Relationships
- Siltation Rates
- Regional Comparisons
- Action Effectiveness
- Cause/effect Relationships
- Reservoir Resource Impacts

THE ECOSYSTEM



Determining Solutions
Applying Actions
Assessing Success

Present and Future

- Watershed Management
- Basin Dredging
- Adjacent Land Configuration
- Water Level Manipulation
- Destratification
- Weed Control
- Taste and Odor Control
- Water Supply Treatment
- Monitoring and Compliance
- Early Warning/ Early Action

TerraMetrics, Inc.

The MASTERS DREDGING COMPANY, Inc.

RESERVOIR MANAGEMENT AND RENOVATION
Addressing Problems in Multipurpose Reservoir Systems

"AquaMetrics": Services and Products......A Preliminary Document

AquaMetrics ...A total approach for management and renovation of reservoirs for water supply, recreation, flood control, and other multipurpose uses.

This document prepared by Jerry deNoyelles, Ph.D. Senior Aquatic Ecologist, University of Kansas and TerraMetrics, Inc, is a further attempt by TerraMetrics, Inc. of Lawrence, KS and Strategic Weather Services, Inc. of Philadelphia, PA to develop the concept of the joint enterprise, "AquaMetrics", so named for now. Here we will begin to identify all services and products to be provided by AquaMetrics. The description of each developed here is brief for now and is primarily intended to direct the initial consideration of patent and other means of protection for each part and for the whole. Some background information is provided first and included throughout are a number statistics that help to assess the importance of reservoirs to society and the extent to which they are experiencing various types of problems.

For the purposes of this document reservoirs and lakes are basins of standing water ranging greatly in size with the flow of water through them reduced below that of the streams and rivers entering. Both "behave" in most of the same ways, are affected by most of the same environmental conditions, can provide most of the same resources, and can require most of the same types of management and renovation. Reservoirs are constructed by human means while lakes are of natural origin. Reservoirs are more often the focus of management and renovation because they are constructed at great expense to serve particular continuing needs. Also, more often they are placed in locations where there are few natural lakes thus they are more likely to be in environments more hostile to their continuing existence. More than two million ponds and reservoirs of all sizes have been constructed in the US this century and many more worldwide. In the US nearly 1000 reservoirs are larger than 1000 acres with about half of these being federally operated. The lower half of the continental US has the greatest number of reservoirs, particularly the central states of Kansas, Missouri, Oklahoma, Arkansas, and Texas which have 249 of the 970 largest reservoirs in the US (see attached figure). A typical Kansas reservoir, 7000 acres in size, constructed in the 1970's cost a total of $50 to $60 million dollars.

The attached diagram titled "Reservoir Management and Renovation – Addressing Problems in Multipurpose Reservoir Systems" serves as an outline of the various activities that we identify as being related to developing and implementing solutions for particular reservoir problems. These activities become the work and involve the products of AquaMetrics as will be further described in this document. As indicated by the attached diagram, a reservoir, though of human construction, is an ecosystem and functions much like a natural lake being a system with many interacting and

interdependent parts. These parts can be more coarsely viewed as the reservoir and all of the other systems connected to the reservoir within its drainage basin including the land and other aquatic systems like ponds, wetlands, and streams. More finely viewed, parts include particular species of plants and animals and the physical and chemical conditions/components like temperature and the dissolved nutrients in the watershed or in the reservoir water. Changes in the structure or functioning of particular parts, whether coarsely or finely viewed, and the ensuing "chain reactions" of these changes affecting other parts is the normal operation of an ecosystem. Certain changes can also lead to undesirable conditions and the problems that society must solve in order to maintain the intended uses of these resources.

More than half of the population of the US receives some drinking water from reservoirs. In the National Recreation Lakes Study authorized by the 104th Congress and recently completed, the economic impact of recreation for the 490 federal reservoirs larger than 1000 acres is determined to be currently $44 billion a year and a total employment of 637,000. The economic impact of recreation for the several thousand other reservoirs larger than 100 acres and the economic impact of all reservoirs in terms of flood control protecting lives and property are incalculable.

Problems in reservoirs today that most often require particular management actions involve the quality of drinking water and recreation and the water storage capacity for flood control and power generation. We build reservoirs where there are few natural lakes, that is why we put them there to serve many different purposes, but we also expect that the local environment is often not very supportive of their continued existence. There are few natural lakes in these areas mostly because the soils are naturally very erodable and can be disturbed even more by human activities. Thus, the reservoir acts as a settling basin where the process of siltation deposits soil, clay, and smaller rock particles filling the basin in 100 to 200 years. This is the actual projected life expectancy of most reservoirs when they are built and far shorter than the tens of thousands of years that most lakes exist. As reservoirs fill with these materials, three to five times more rapidly in their upper reaches where the streams enter, the ever expanding shallow zones reduce the quality of the water and habitat as well as the original storage capacity for flood waters and power generation. Two hundred of the largest reservoirs in the US are now more than 40 years old. Over the next century when most of the reservoirs that we have now constructed have filled, at least to the point of ending their useful life, what will we do?

We have already built reservoirs in nearly all of the best places. Excavating the old reservoirs will require moving 15 to 30 times more material than originally moved to construct the dam. It will also be necessary to find a location for all of this material, close by to reduce costs and that can be disturbed in such a manner. Also, because so much urban and rural development has steadily surrounded our reservoirs, we cannot simply continually raise the height of the original dam and the contained water level. Obviously, we must develop and implement new management strategies to maintain the intended uses of these reservoirs and extend their life expectancy.

The general course of action taken by AquaMetrics for reservoir management and renovation outlined by the attached diagram begins with examining, both historically and in the present, particular parts of the ecosystem to describe the nature and source of the problem. The next step is to identify the conditions of particular parts of the ecosystem, both coarsely and finely viewed, which have changed to cause the problem to develop. Previous attempts to control the problem are then assessed for their effectiveness in the past and present before AquaMetrics begins to determine what future courses of action are necessary. New actions or continued use of successful past actions are then applied to those portions of the ecosystem connected to the previously determined cause(s) of the problem. An ongoing program of action is continually assessed by AquaMetrics for its effectiveness, modified where necessary, until the problem is determined to be under control and the reservoir is satisfactory serving its intended purposes. This document will now describe each activity identified in the attached diagram as each is involved in the more general problem-solving course of action just described.

Locating Sources, Identifying Causes, Evaluating Actions....Past and Present.

1) Ecosystem history - Our program begins with determining the history of the reservoir construction and subsequent development as well as the natural history and the history of human activities within the watershed of the reservoir. Accomplishing this work mostly requires being able to identify the different sources of information for the various components of such a history. These sources include a number of state and federal agencies or offices responsible for gathering and storing such information. There is also important information concerning the early natural vegetation of the land before settlement in various types of public records such as old survey records going back to the original settling of the land by Europeans during the past three centuries. The past features of any ecosystem, here the reservoir and its watershed, continue to affect the current functioning and may provide important clues to help to identify management strategies to address particular problems in the present and future. For example, it is important to know the extent to which the current vegetation covering the watershed is not native to the region and thus not as well adapted to the climate and other conditions of the region. This provides important information about the natural stability of the reservoir/watershed ecosystem in terms of how easily it can become disturbed thus causing particular problems to be considered for management and renovation.

2) Problem description - All current problems within the reservoir that could involve either management or renovation actions are identified through a two-part process. Two parts are evident recognizing that certain observable problems in the functioning of the reservoir like declining sport fish availability, excessive plant growth, and taste and odor in drinking water may actually be symptoms of more basic, though less recognized, problems in the functioning of the reservoir. The latter, once the connections to the observable problems are understood, also become the focus of management and renovation. Such more basic problems could include excess nutrients or soil entering the reservoir due to some disturbance in the watershed. This two-part process begins with identifying the more observable problems as described by the current and past reservoir

personnel and the public. Such descriptions may specifically identify the more fundamental problems. More often these descriptions of the more observable problems only provide clues which are then used by the scientists who can relate the one to the other as the real causes for the observable problems are determined in the series of steps, (3) through (9), to be described next.

3) Problem chronology - Identifying the chronology of both the observed and the fundamental problems is to study the past records kept for the reservoir by managers and others responsible for using and documenting the various resources that the reservoir and its watershed provide. This can include such information as fish harvest records, weed removal records, and public complaints recorded at water treatment facilities concerning taste and odor of drinking water. This information is important for further connecting the observed to the fundamental problems as discussed above. This also begins the process of identifying the cause and effect relationships between particular characteristics of the reservoir/watershed ecosystem and the problems. Discovering these relationships leads to the identification of key conditions in the ecosystem to be changed either by management or renovation actions to solve or control the problems. For example for a weed growth problem it may be determined from past records that years of greatest incident correspond with certain predominant agricultural practices in the watershed or instead, with certain annual water level manipulations performed by managers to prepare the reservoir for flood water or sport fish spawning. Also, taste and odor conditions in drinking water taken from the reservoir may only occur in years of heavy plant growth in the reservoir, but only certain types of plant growth only in certain locations. Here for this example the next step is to relate particular conditions of nutrients, weather, etc. to these particularly undesirable plant growths. These cause and effect relationships are first examined historically up to the present by various means further described next.

4) Remote sensing analyses - Certain information for the reservoir and its watershed is best gathered with the many new remote sensing technologies continually being developed. Some have now been providing information for more than a decade. Particularly the technologies employing the use of high elevation sensors from airplanes and satellites serve the important need for information gathered across large expanses of water and land. Quantifying the extent of aquatic weed growth following certain nutrient changes in the reservoir water or quantifying the extent of shallow zones developing due to siltation or more rapidly following water level manipulations can only be done with analyses of data gathered in such a larger scale manner. The watershed is generally 10 to 100 times or more larger than the area of the reservoir thus characterizing features of this land and other water bodies draining into the reservoir must be accomplished in part from an elevated vantage point. Key features of this land and upper water bodies can be first examined historically for characteristics most affected by human activities and changing weather conditions as the most likely candidates causing changes leading to problems. The terrestrial vegetation covering the land is a particularly important characteristic controlling the influence that this land has on the reservoir receiving its drainage. There are many conditions of this vegetation that can be measured and described by recording finely distinguished differences in its "greenness" as sensed by the many different wavelengths of energy emitted by vegetation that can be remotely recorded. Our group

of scientists (see attached) as part of TerraMetrics, Inc. (TMI) is already working on another venture with Strategic Weather Services, Inc. (SWSI) using this type of greenness information. TMI has uniquely developed certain greenness parameters to measure agricultural production that can then be projected into the future using the weather analyses that SWSI is uniquely able to perform. Together, we are now discovering, beginning with historical analyses, that terrestrial greenness and weather in the same ways that they can be related to agriculture can also be related to a number of plant growth conditions in the reservoir and associated problems. Some of this technology can also record greenness of the reservoir plants directly but this is still limited because the water medium masks recording this information for all but the shallowest surface conditions. Our group is at the cutting edge of the development of this greenness technology and we are also directing its development for more direct aquatic use. For more details see the attached description of this work titled "Terrestrial Greenness Related to Weather Parameters as Indicators of Reservoir Conditions".

5) Weather relationships - It has long been recognized that certain weather conditions either directly or indirectly affect the functioning of reservoirs both over the long term and more immediately on a day to day basis. Weather, particularly the solar radiation as it affects water temperature, water circulation, and plant growth and the precipitation as it affects movement of materials from land to water, should be strongly correlated in some way with all of the reservoir problems that we identify. Though in principle this is obvious, there has been little attempt by scientists to use weather as a component of cause and effect relationships or to use weather projections as a predictor of other reservoir/watershed conditions and problems. Together, TMI and SWSI are now beginning to work in both of these areas, first with historical records of particular problems in particular reservoirs and the records of weather conditions at the time. Further development of the use of weather analyses in reservoir management and renovation will be discussed in other sections, particularly at the end in section (20).

6) Siltation rates - All reservoirs will ultimately cease to exist, thus it is only a matter of time, extended only by major human intervention, as described in the introduction. More than 50,000 reservoirs larger than a football field have been built this century in the US, most between 1920 and 1980. Consider the 35 year-old John Redmond Reservoir, the fourth largest reservoir in Kansas in total original size. This reservoir by siltation has decreased in size by 30% up to the present and over the next 38 years is projected to decline to half of its original constructed volume. Today, this reservoir is close to the end of its useful life span in terms of the resources that it is able to provide. The rate of siltation is the most fundamental problem for reservoirs, the problem that must sooner or later address be addressed in all reservoirs and the problem to which all other problems can ultimately be attributed. Therefore, determining the rate that a reservoir has been filling over time by siltation is necessary for developing both short-term and longer-term management strategies to address all types of problems. Today siltation rates are only monitored with some regularity in federal reservoirs, thus in less than half of our larger reservoirs in the US. This is done by measuring basin depth every ten of so years from a standard height at several locations in the reservoir. By difference the rate is calculated for depth loss over the years. Little has been accomplished to extend remote sensing

technologies to performing this measure since the water medium still limits current sensors from recording much below the surface. However, our scientists are considering a different approach. The reservoir surface area can be accurately remotely sensed from the time of original construction to the present using various types of older aerial photography and more recent satellite sensors. The reservoir water height through time is also generally known since it is the most common parameter routinely recorded for federal and other reservoirs. Then, knowing the original constructed contours of the basin from historic contour maps and blueprints, changes in surface area can be converted to loss of depth for the many reservoirs that have not been periodically depth sounded. By taking advantage of the ability of aerial remote sensing to survey large geographic expanses, siltations rates for entire regions could be routinely developed.

7) Regional comparisons - Some of the environmental conditions that affect the functioning of the reservoir/watershed ecosystem are similar within large geographical regions. These include weather conditions, soil and vegetation types, geology, topography, and human activities. In the historical investigation of reservoir problems described above finding a consistency to the types of problems within a region can indicate the importance of particular regional conditions in the cause and effect relationships being determined. Within a region of particular prevailing conditions all reservoirs may be more vulnerable to certain types of disturbances and thus all more effectively managed or renovated in certain ways. For example there are consistent problems observed in reservoirs constructed in mid-continent regions worldwide with a temperate climate, with grassland vegetation growing in deep rich soils with a higher clay content, and with predominance of agricultural land use. These reservoirs all experience accelerated nutrient enrichment and siltation rates from their watersheds. Particular actions must be taken to reduce erosion in the watersheds, to construct original basins or renovated ones with greater average depths, to create sedimentation basins or traps near reservoir inlets, and to construct water treatment plants with certain designs allowing for more effective processing of the domestic water supply. All of these actions will be discussed further in later sections of this document.

8) Action effectiveness - Assessing the effectiveness of management and renovation actions taken in the past provides not only trials of what could be done in the future but also important clues to the cause and effect relationships being sought, first here in the past. These past actions are in affect scientific experiments manipulating certain suspected controlling variables with the recorded outcome being an assessment of the importance of these variables to both the development and the control of the problem. For example even stronger measures have been taken in recent years to reduce soil erosion in watersheds. Though today we more clearly recognize the impact of siltation on reservoirs, most soil erosion reduction measures are still in response to the relationship between agricultural productivity and soil conditions. Yet, today taste and odor problems in reservoir water as described further in other sections still continue to be the type of problem most often identified by the public requiring specific action by water supply technicians and officials. Maybe this problem is not only related ecologically to siltation and the expanding shallow zones of reservoirs. Perhaps, we must also provide more control over the dissolved nutrients that leave the land, particularly agricultural land. In

the reservoir these nutrients stimulate even more excessive plant growth that further contributes to the taste and odor problems. At the same time even with erosion control measures extensively used today, reservoirs are still filling rapidly with the accompanying threat of accelerated plant growth. Thus, erosion control must be extended to capturing what does erode before it enters the reservoir by constructing settling basins that inflow streams pass through as they enter the reservoir as further discussed in section (12).

9) Cause and effect relationships - The eight preceding types of investigations described above are directed to locating sources of and determining causes for particular reservoir problems to eventually determine management or renovation actions to be discussed below. Thus, cause and effect relationships are identified that exist between reservoir/watershed conditions documented in the past and present and the problems they have caused and are causing. There is considerable advantage in first seeking such relationships in the past. The past can provide many years of information for identifying and then confirming particular cause and effect relationships. When limited to just the present these can only be viewed as single cases with no classical statistical replication for sound verification. As hypotheses emerge from these historical investigations they can be tested again in the same ways in the present at the time closest to determining the particular management and renovation actions. The scientists (see attached) working as part of TMI have many years of experience with investigating all aspects, as described in this document, of the complex relationships that exist between reservoirs, their watersheds, and the problems that can develop in either. In spite of the how necessary reservoirs have become in modern society and how threatened their basic functioning has become, it is still rare today to pursue problem solving in reservoir/watershed ecosystems applying the degree of scientific investigation being described here. More often these ecosystems are viewed to be natural thus it is assumed that they can take care of themselves like the rest of our environment is expected to do. We must recognize that not being of natural origin has predisposed these seemingly "natural" resources to a number of very complex problems that threaten their very existence if our careful intervention is not forthcoming.

10) Reservoir resource impacts - Determining the impacts of the problems identified in a reservoir/watershed ecosystem are basic to describing the problem. Though this consideration could have been included in (2), it is best addressed after the more complete historical analysis of cause and effect relationships. Now a more detailed view of all aspects of a problem is possible, particularly how far reaching the problem really is and how much of the reservoir functioning is really impacted, including from a resource perspective. Also, with a more complete understanding of the causes of the problem, what it will take to solve or manage the problem becomes clearer and this is ultimately also part of the impact. For example, periodic taste and odor problems addressed by a water treatment facility result in a particular resource impact that at the very least will have identifiable economic costs and even political costs for the municipal officials who must respond to this most sensitive public issue. Where public water utilities have been privatized, public sensitivity is often even greater for now the expectation and scrutiny of the quality of the water can be even greater accompanying the also very sensitive issue of

privatizing a public resource. However, we recognize that taste and odor problems in a water source are really symptomatic of more fundamental problems in the reservoir/watershed ecosystem. This extends the impact on the resource far beyond the water treatment plant.

Continuing the example of tracing the extension of a problem to broader impact, today the taste and odor problem is known to result from a chemical in the reservoir water called geosmin released naturally by certain plants including algae and by other microorganisms living in the water. It is the excessive growth of these organisms at times that produces so much geosmin that the normal or even accelerated water treatment plant methods fail to remove enough so that it is not detected by the user. This chemical is not known to be toxic, just an "earthy" or "fishy" tasting and smelling one that effects nearly all reservoirs everywhere at one time or another. Human nature is such that the appearance of this condition leads the public, particularly the public in the so-called most advanced societies, to thinking the worst and no manner of convincing can allay the fear of something dangerous being in their water. The impacted resource then extends far beyond just the water removed from the reservoir and treated since the causes and treatments for this problem, like most others, can be traced to the entire network of interacting parts that we know to be the basic functioning of the reservoir/watershed ecosystem. Here, accelerated plant growth is the cause but this then extends the problem even further to the elevated nutrient levels originating from the watershed and to the increasing shallow zones resulting from the ultimate problem of siltation. To manage or renovate for taste and odor problems means to address the entire system or to develop a new technology, in this case a new step in water treatment as will be discussed below, that can intervene at onelevel and solve or control the problem.

Determining Solutions, Applying Actions, Assessing Success....Present and Future.

11) Watershed management - Sources of disturbance in the watershed that can move to the reservoir do so mainly carried by water in surface runoff and in groundwater and can be identified and quantified. Such disturbances most often consist of particulate material that affects water clarity and with settling reduces basin size and of chemicals including nutrient and toxic types that affect basin organisms and human water use. The technologies of remote sensing (e.g., analyzing aerial photography and satellite imagery) and geographic information systems (e.g., computer-based displays and analyses of relationships between features of the watershed) play a central role in this type of work in watersheds. TerraMetrics, with its cooperating scientists at the University of Kansas have 25 years of experience with using and developing these technologies for watershed analyses of many different types. Computer software and particular types of analyses and interpretations are among the services and products that can be considered for patents and other types of protection. This work supports reservoir management by identifying conditions in the watershed causing problems in the basin that then can be managed in the watershed to reduce the problems in the basin. The larger the reservoir in water volume generally the larger is the watershed that maintains this volume in any particular climatic region. The larger the watershed the more complex it tends to be particularly in

terms of the variety of different land types, vegetation types, and other types of water bodies draining into the reservoir. For example the 30,000-acre Oologah Lake, which is the reservoir that provides about half of the water supply for Tulsa, OK and one that some of our scientists are currently studying, has a watershed of about two million acres. Within this watershed are large portions of forest, native prairie, and cultivated land and more than 30 other reservoirs larger than 50 acres totaling more that 13,000 surface acres of water. There are also many more small ponds and wetlands and all of the interconnecting streams leading to the main reservoir. Relating watershed conditions to reservoir conditions also requires direct analyses of the reservoir and also possible direct management and renovation of the reservoir discussed further below.

12) Basin dredging - As stated earlier the greatest threat to our reservoirs is the process of siltation most affected by where the reservoir was originally placed and by human activities in the watershed. We recognize for most reservoirs built anywhere worldwide a projected life expectancy at the time of construction of about 100 years, the time when more than 50% of the normal operation basin will be filled with silt. We also recognize that this is the time period after which most will cease to provide all of their intended functions though we will still have all of the same needs for these functions such as flood control, water consumption, and recreation. Excavating silt-filled basins full or nearly so, finding a place for so much material, and accomplishing all of this at about the same time in the future since most reservoirs are about the same age and fill at about the same rate are beyond any current perception of our means. If societies worldwide begin planning now, most are not, we would develop methods and machinery for the special tasks of dredging reservoirs, not entire basins for most but rather the upper arms. The dredging partner of TMI, The Master's Dredging Company, Inc. of Lawrence, KS, already has developed the largest dredges in the US for reservoir work and certain mechanics of operation currently not available on the market. By dredging the upper arms now, silt is removed from where it is most rapidly accumulating and from where it is already affecting the quality of the rest of the reservoir as discussed in this document. By excavating upper basins even deeper than they were originally, settling basins can be formed to serve as silt traps. By leaving in place the access infrastructure to these settling basins, they can be conveniently returned to every 20 to 30 years as a long-term maintenance strategy.

13) Adjacent land configuration - The cost-effectiveness of reservoir dredging relies heavily on not moving the spoils great distances. This material can be deposited close to the site by contouring the generally flat landscape around many reservoirs into more recreational areas like golf courses and into more wildlife habitat, particularly wetlands. . Constructing new wetland habitat also has economic value. Since federal regulations now require that whenever proposed development may destroy wetland habitat and there is no alternative for protecting it, in order to proceed there must be a mitigation or creation of equal wetland habitat near by. This is already spawning the business of wetland banks where any number of mitigation requirements can be served for a fee at one location in the area. With reservoirs so liberally scattered across the US, this could provide a valuable and profitable service to a very broad area. Any sort of use of the spoils of dredging like those described above necessitate the skillful movement,

placement, and preparation of these materials to accomplish the configuration tasks. Working with these water saturated and very fine grained materials require the use of new methods and equipment not ordinarily used for the far more common river dredging where the sand, typically not available in reservoirs, is transported away as a product for use in construction. TMI's dredging partner is already developing such methods and equipment.

14) Water level manipulation - The longer-term declines in water levels due to siltation must ultimately be addressed by dredging as discussed in detail earlier. Water level manipulation is used by reservoir managers to prepare for spring and early summer floods and for wildlife development. However, this may exacerbate all of the other problems related to water level discussed in this document. Early in the spring many reservoirs are intentionally lowered but if the later rains are less than expected, the reservoir remains low all summer creating more plant growth and more bacteria and fungi growth, thus greater related problems. When more water is released than necessary there is less capacity for other uses including drinking water, irrigation, and recreation. When too little water is released, the consequences are devastating as was the case with the floods of 1993 in the central US. For water level manipulation there is great need for making more informed decisions as will be further discussed in (20) with the use of weather and other projections as part of the decision making process.

15) Destratification - The natural thermal stratification of reservoirs in affect also produces shallow water and some of the associated problems discussed in this document. Stratification naturally occurs with warmer weather as surface water is heated more rapidly than deeper water during the spring and early summer. This can rapidly form a warm and thus less dense surface layer a few meters deep in the reservoir that physically does not mix with the colder and thus more dense deeper water. Stratification also creates other management problems as the deeper water declines in oxygen and increases in ammonia and hydrogen sulfide as the summer progresses producing very inhospitable conditions for sport fish and even leads to other types of taste and odor problems. With stratification nutrients tend to build up in the deeper water due to settling of organic matter from above and the resulting increased decomposition that releases these nutrients. The deep nutrient-rich water does not receive enough light for summer algae growth but is later mixed to the surface in the early fall when the entire reservoir water column becomes mixed again as it cools. This often causes another "burst" of microorganism growth in the fall at about the time when taste and odor problems are about to begin as will be discussed in section (17).

The thermal stratification of a reservoir is sometimes managed because of the adverse effects noted above. Here there is an attempt to physically break down the thermal layers. This is attempted either by pumping compressed air deep into the water column to cause mixing or by selectively drawing water out of a particular thermal layer for the normal outflow from the reservoir. Certain volumes of continuous outflow from a reservoir are required by law to maintain flow in the stream below. Compressed air or other mechanical mixing systems are very expensive and must be set up well in advance

to be quickly effective when conditions require such treatment. Selective discharge must also be initiated well in advance of the onset of the problems caused by stratification. Accurate prediction of spring and summer temperature conditions would allow far more cost effective and successful management actions to be taken as will be discussed further in section (20).

16) Weed control - Controlling excessive plant growth of a number of different types is given more detailed attention here since these organisms produce many of the problems in reservoirs that require management and renovation actions. Plant growth in reservoirs is driven by plant nutrients, particularly nitrogen and phosphorus, dissolved in the reservoir water. Eutrophication is the process of increases in nutrients and accompanying plant growth that occur in reservoirs either by natural processes or processes greatly influenced by human activities. Plant growth is also highly dependent upon available light that beneath the surface of the reservoir is controlled by the clarity of the water. The types of plant growth in reservoirs, thus the particular accompanying problems, are related to the clarity of the water along with the total amounts of nitrogen and phosphorus and, as will be explained below, also the relative amounts of nitrogen verses phosphorus or the N:P ratio.

Water clarity is a function of the amount of suspended matter in the water, mostly silt and microscopic algae. Floating flowering plants and suspended algae prevail with reduced water clarity and elevated nutrient levels. With low amounts of nitrogen present relative to phosphorus (N:P ratios less than about 5:1) only a certain type of algae dominates, particular species of "bluegreen" algae which are able to fix or use atmospheric nitrogen. These algae in this way are like terrestrial legumes in being able to use a type of nitrogen that is naturally in high supply in water and air but other plants are unable to use it. The bluegreen algae are the plants most often associated with the production of geosmin in a reservoir. They either produce geosmin in their cells that is then released upon death and decomposition or the bacteria and fungi decomposing them produce the geosmin. These algae are also greatly favored by reduced water transparency because of their unique ability to be very buoyant from trapped gas produced by their own growth. They are a larger type of suspended microscopic algae not readily eaten by the animal food chain in the reservoir. Not being eaten leads to even greater accumulations of their biomass in late summer and fall in temperate climates. Such masses at the surface also cause recreation problems as this material accumulates along the shoreline.

With greater water clarity certain algae growing attached to bottom surfaces and certain rooted flowering plants dominate with elevated nutrient concentration in the water. In some reservoirs, particularly observed in the California, the water can be very transparent due to greatly reduced erosion but still have high nutrient levels due to fertilizer runoff and/or sewage contamination (human or livestock). Here the bottom algae, including some bluegreen algae, have also been associated with geosmin production. In the fall these surface or bottom algae naturally die and decompose rapidly leading to the common geosmin incidents in the late fall and early winter in many reservoirs. Large growths of flowering plants, rooted or floating, are less often associated with geosmin incidents either because they produce less in their bodies or less is produced with decomposition

since their structure is much more coarse compared to algae and they decompose slowly. The problems caused by flowering plants are mostly physical ones including the disruption of habitat for fish growth and the disruption of the physical acts of fishing, swimming, and boating, even commercial navigation. Flowering plants are particularly a problem in low erosion areas and in the more southern temperate and tropical regions where these flowering plants do not naturally die back during the winter thus their biomass accumulates year after year.

Management and renovation actions to control these various types of plant-related problems involve particular actions specifically directed at controlling the type of associated plant. Controlling plant growth in reservoirs is a necessary action for addressing most of the reservoir problems discussed in this document. There are many situations where conventional methods are not working and there are opportunities for new more effective actions to be developed and implemented. As part of TerraMetrics, scientists and mechanical engineers are working together to develop new actions with the former providing new insights into the reservoir conditions that excessively stimulate the growth of these plants. At the same time the latter are providing new actions to physically remove these plants or to restructure through dredging certain habitats in the reservoir that have changed due to siltation. For example with continuing efforts to reduce soil erosion to preserve agricultural productivity and to reduce siltation rates in reservoirs, water clarity has been increasing in many reservoirs in recent years yet excess nutrients still enter from other sources. Controlling the inflow of nutrients has become even more important and our group is working on new methods to remove nitrogen and phosphorus at their domestic and agricultural sources. We are also developing new methods to capture these nutrients along the way within the watershed drainage system before they reach the reservoir. For example for the latter, certain management practices in the smaller farm ponds and streams that nearly all agricultural runoff passes through can deposit these nutrients in contained sediments and vegetation for indefinite periods of time. Also, as part of the adjacent land configuration accompanying dredging as discussed in (13), settling basins and wetlands, through which the runoff is directed to pass, can be constructed in new more effective ways. There are new ways to construct the former such that they are particularly effective at removing nutrients attached to the silt particles. The latter, being the most productive type of natural plant habitat, can be strategically located as part of the use of dredging spoils to intercept within the natural wetland plant growth much of the nutrient load heading toward the reservoir.

Our group is also improving the process of mechanically shredding and promoting the natural decay of floating and rooted flowering plants as an alternative to using herbicide controls. Herbicide use in reservoirs, particularly in those used as water supplies, has declined in recent years with greater regulation over the use of such chemicals, with their increasing cost, and with little advance in improving their effectiveness. Mechanical means of control are now more often preferred. The recent design, construction, and use of the "Aquaplant Terminator", a device aptly named by its inventor our partner The Masters Dredging Company, Inc., is revolutionizing this action. This device as a boat with special attachments is mechanically able to shred floating or near surface flowering plants at a rate considerably faster than any other mechanical device on the market.

Patents are pending for particular features of the construction of this device. Our scientists and mechanical engineers are now beginning the planning phase for another mechanical device using some of the features of the "Aquaplant Terminator". While navigating the reservoir this device could pass large volumes of water with high concentrations of floating bluegreen algae through specially designed chambers. These chambers will be designed to critically alter cell structure and clumping followed by passing these plants back into the reservoir in a more harmless condition. Being microscopic, even though sometimes in floating masses, these plants cannot be killed by mechanical shredding and they cannot be harvested. However, we believe that it may be possible to alter their structure and functioning so that less geosmin is ultimately released either directly upon their death or by the microorganisms decomposing them.

17) Taste and odor control - Seeking solutions to this problem begins with identifying the sources of these conditions within the reservoir itself. In recent years as noted above it has been discovered that this condition is most often due to the presence of a chemical called geosmin present in the reservoir water before it reaches the water treatment plant. This problem as it exists today everywhere in the US and abroad generally appears in the late summer and fall causing the greatest occurrence of public complaints to plant operators and to the local political establishment. Extreme treatment measures are often pursued at the water treatment plant and are usually ineffective at removing the geosmin as will be discussed further in (18). Alternative water sources become the only solution but are often not available. Currently there is no evidence that geosmin in the concentrations found in reservoir water or in the distributed water is toxic either to wildlife or to humans. It does create a "musty" taste and odor at very low concentrations that is objectionable to the user who then typically assumes that there must really be any number of "dangerous" chemicals or organisms present thus the high incidents of ensuing complaints.

Certain key aspects of effectively dealing with this problem before it reaches the water treatment plant (within treatment plant actions discussed in section 18) are currently not adequately addressed. This begins with identifying the source of the production of geosmin in the reservoir or perhaps in the watershed. Our scientists have been studying this for several years and are now close to discovering the source. Conditions in the reservoir most closely related to the appearance of geosmin are conditions affecting certain types of plant growth. These were described in (16) for certain characteristics of the reservoir water. In terms of the physical structure of the reservoir basin, conditions include the expansion of shallow water zones overlying silt deposits, silt deposits periodically exposed to the atmosphere, high nutrient levels in shallow water, and a greater fraction of the total volume of reservoir water occupying increasingly shallower areas. These reservoir structural conditions are clearly related to siltation and basin filling invoking the management and renovations actions involving dredging as discussed in (12) and (13). These structural basin conditions and the plant conditions discussed in (16) are not often considered all together when developing management and renovation actions as we are doing in our work with taste and odor problems. Now such considerations will open the way to developing actions from several directions to reduce the concentrations of geosmin reaching the treatment plant by reducing the production in

the basin. The geosmin that does reach the treatment plant is also being targeted in new ways as described next.

18) Water supply treatment - The reservoir condition that most often produces a problem that must be treated in the water received by a water treatment plant for domestic water supply is once again the high levels of the chemical geosmin and the accompanying objectionable taste and odor for the consumer. Currently attempts to control this condition within the water treatment plant focus on its removal by chemical or biological means. The financial costs for addressing geosmin problems either within the reservoir or within the treatment plant can be quite substantial as shown recently for reservoir water supply systems in Kansas. The City of Wichita has allocated $500,000 to control nutrient levels in their reservoir to reduce the production of geosmin by aquatic plant growth. The City of Emporia has installed an ozonation component for their treatment facility for removing geosmin at a cost of $830,000. The City of Lawrence, after having to shut down their treatment plant and use an alternative water source for nearly two months in the fall and winter of 1995-96, is now assessing the capital improvements needed after another high geosmin episode occurred in the fall and early winter of 1997-98. As discussed above this problem worldwide grows worse as reservoirs age and fill with silt. Objectionable taste and odor is registered by the consumer when geosmin concentrations rise above 5 nannograms (ng) per liter (nannogram = one trillionth of a gram) in the water from the tap. Concentrations of geosmin above 20 to 50 ng/liter require complicated and costly treatment efforts that are ineffective at concentrations above 100 ng/liter. It is not uncommon to record concentrations of geosmin in reservoirs at above 200 ng/liter.

Today most efforts to chemically remove geosmin at the treatment plant involve the increased use of adsorption of geosmin on powdered activated carbon (PAC) which is costly and not effective at higher geosmin levels as described above. PAC also interferes with other steps of the water treatment process apart from geosmin control such as disinfection and filtration. Alternative use of granular activated carbon (GAC) and ozonation when PAC fails has been tried with similar problems of effectiveness and cost. Processes for geosmin treatment must be improved and our scientists are currently working from several directions including refinements in each of the above methods, different ways of using them together, and new methods involving biologically active filters to attack and degrade the geosmin. We are also attempting to determine if other steps in the routine treatment of drinking water cause more geosmin to be retained in the final product or even produced along the way.

19) Monitoring and compliance - Applying management and renovation actions to solve or control reservoir problems as have been discussed in this document always involve monitoring many different physical, chemical, and biological conditions in the reservoir/watershed ecosystem. This begins with gathering background information for determining the nature of the problem and the actions to be taken. While an action is being taken certain conditions must be monitored to follow how the reservoir is responding to the treatment or being disturbed in undesirable ways by the treatment. Finally, monitoring continues for some time into the future to determine the effectiveness

of the action. Typically 30 or more types of measurements are taken in the reservoir and in the watershed. Some are physical such as water temperature and clarity in the reservoir and land runoff and erosion rates in the watershed. Some are chemical such as nitrogen and phosphorus dissolved in the reservoir water and the amounts of these plant nutrients applied to the land and ultimately flowing from it in surface runoff or in ground water. Some are biological such as the amount and types of suspended algae and rooted plants in the water and for the land the amount of vegetation cover and thus potential land exposed to the forces of erosion. The technology of environmental monitoring is continually changing with the development of more dependable sampling tools, more sensitive analytical equipment and methods, and more cost effective types of all of this technology. Scientists in our group with TMI as they use these technologies have been continually improving them and contribute directly to new technology development.

Considering the subject of compliance, for some time to come there will be considerable public concern over water resources of all types and this results in involvement of many government agencies and other organizations with these resources. This involvement ranges from actual jurisdiction over certain matters to various degrees of influence over other matters. Particular management or renovation actions described in this document may require official types of compliance, even permits, or at least cooperation from certain parties to be most successfully completed. Knowing how to work with this network of involved parties is very important to the success of any action. The scientists working as part of TMI are very experienced in these matters and some have also worked as part of this network at the federal, state, and private levels for years. The network of influential parties will differ depending on the ownership of the reservoir and land within the watershed. Most states have the following types of reservoirs based on ownership or designated responsibility. Federal reservoirs include those operated in some way by the Corps of Engineers, Bureau of Reclamation, Tennessee Valley Authority, Forest Service, National Park Service, Fish and Wildlife Service, and Bureau of Land Management. Other reservoirs are operated by the state, by particular watershed districts within the state, by municipal and city governments, or by private parties. In any part of the US and in most other nations there will be 10 or more federal, state or provincial, local, and private groups with degrees of influence from compliance to providing significant assistance and cost effectiveness.

20) Early warning/early action - Weather and weather-related conditions have been considered throughout this document as they relate to dealing with reservoir problems. Including weather analyses and projections in the process of projecting future reservoir problems and timely implementation of actions is another unique feature of our approach to reservoir management and renovation. A further consideration of the role of weather analyses and weather projections are provided here. Also, since weather analyses and projections are protected in various ways by patents and other means through Strategic Weather Services, Inc. this would also automatically protect any reservoir management and renovation strategies relying on their use.

First a few examples of the more obvious relationships between weather and the reservoir problems discussed above. Beginning with the production of geosmin in the reservoir

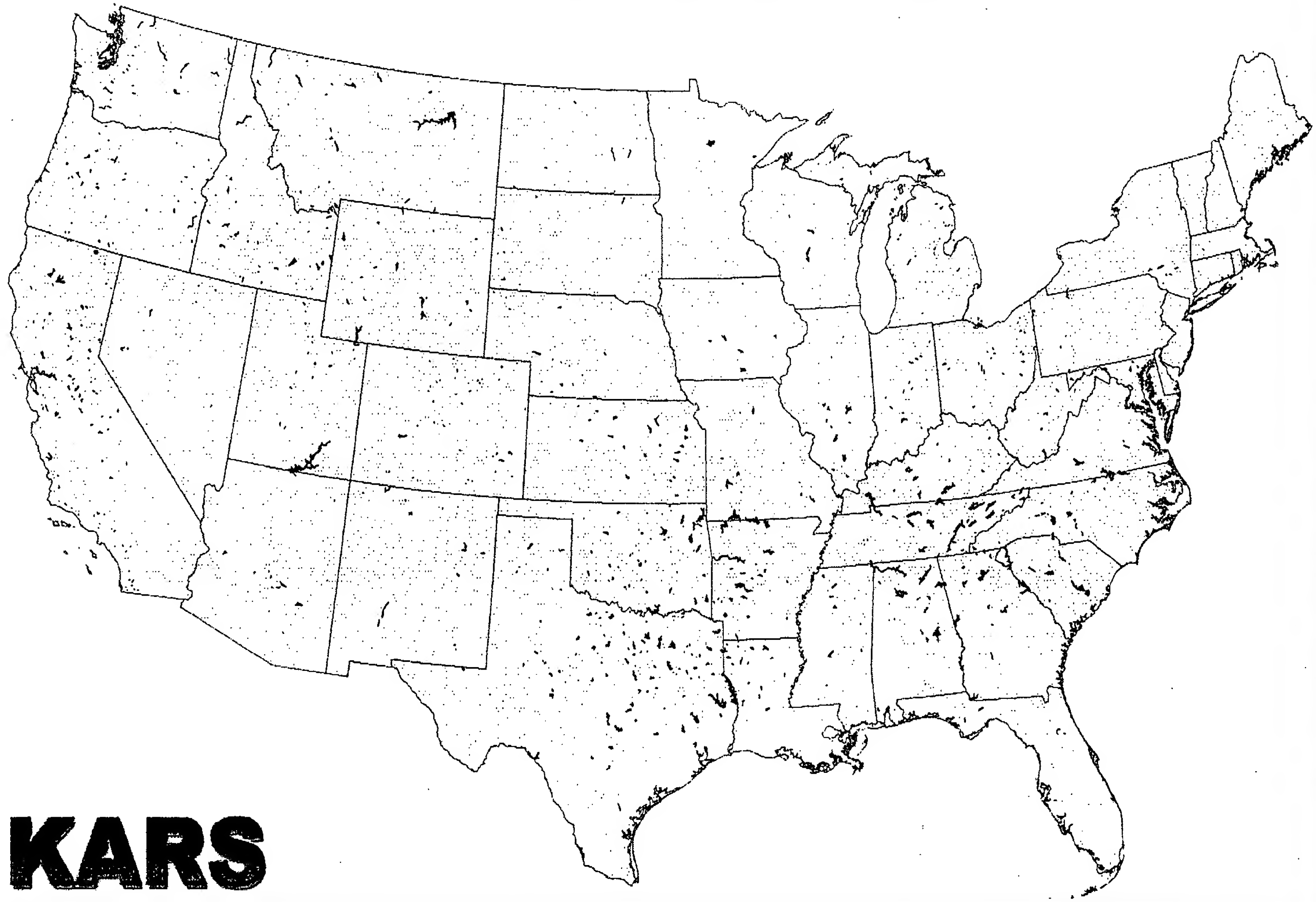
and weather, warm and sunny spring and early summer weather conditions stimulate the growth of aquatic plants, particularly the algae. Higher nutrient levels are also required for this growth in the reservoir and such nutrient levels are most often produced by watershed runoff, thus by precipitation as another predictable weather condition. Shallower water levels created over time by siltation or immediately by manipulation can be related to weather and produce warmer water that is thus more exposed to high light conditions and nutrients. Thermal stratification is weather related and in affect also produces shallow water zones intensifying certain plant problems and creating others as described in (15).

Now a few examples of specific management and renovation strategies related to the above examples of weather relationships. The longer-term declines in water levels due to siltation will ultimately have to be addressed by dredging as discussed in detail earlier. Short-term changes in water levels are used by reservoir managers to prepare for later spring and early summer flood control requirements but this may exacerbate other problems as noted in (14). Here to there is great value in predicting well in advance the extent of the rainy period and thus an amount of water to be released. With precipitation comes runoff and the movement of silt and nutrients to the reservoir. The nutrients most often stimulating plant and secondarily other organism growth are nitrogen and phosphorus. These are also two of the nutrient chemicals most often used to fertilize agricultural lands in the spring. Considerable expense and effort are directed to manage these nutrients in watersheds to protect lakes and reservoirs throughout the US and worldwide from the variety of problems caused by excessive plant growth. With a more accurate prediction of spring rains, thus potential nutrient runoff, particular management strategies concerning the application of agricultural fertilizers can be more properly selected and implemented. Also, the management practices for controlling plant growth including, chemical herbicide application and the now more preferred mechanical removal, can be prepared for well in advance and initiated at the best time. Advance warning will also allow the water treatment plant to be properly prepared for a geosmin event. Finally, even the thermal stratification of a reservoir is sometimes managed because of the adverse effects noted in (15). Here there is an attempt to physically break down the thermal layers more often by pumping compressed air deep into the water column to cause mixing. This is very expensive and a difficult procedure to prepare and an accurate prediction of spring and summer temperature conditions would allow far more cost effective management decisions. These are just but few of the creative ways that weather projections and reservoir management and renovation can be used in concert.

Finally, as another way of advancing the use of weather analyses to address reservoir problems, we are attempting to find relationships between strongly weather-related conditions, like plant growth in the watershed, and particular reservoir problems. Finding such relationships will help to further identify important types of weather analyses to examine and will also provide other indicators of reservoir conditions not used by others. This adds another unique approach to our program for addressing reservoir problems. The scientists working with TMI and recently with SWSI are now examining relationships between remotely sensed terrestrial greenness as discussed in (4) and

reservoir problems of various types. Here we are beginning by using some of the same weather and crop greenness relationships already in use by TMI and SWSI as they have been developing methods for projecting crop production. This is being extending to our reservoir program by developing a means of projecting reservoir greenness and thus the related reservoir problems providing this unique and weather-related feature to our program. Reservoir greenness cannot be directly remotely sensed now due to limited satellite technology in this area as described in (4). For more details see the attached description of this work titled "Terrestrial Greenness Related to Weather Parameters as Indicators of Reservoir Conditions".

970 of the Largest Reservoirs in the Continental United States — 1980



KARS

Kansas Applied Remote Sensing Program

Source: U.S. National Atlas

RESERVOIR MANAGEMENT AND RENOVATION

The AquaMetrics Team

TerraMetrics, Inc. Lawrence, KS *program development* *program coordination*	Sam Campbell, President Scott Campbell, MA, Field Director Carolyn Shelton, MBA, Program Manager
Consultants for TMI Lawrence, KS *aquatic ecology* *monitoring and water chemistry* *habitat restoration* *compliance*	Jerry deNoyelles, PhD, Reservoir Ecologist Val Smith, PhD, Ecosystem Ecologist Donald Huggins, PhD, NPSP Specialist Sharon Dewey, PhD, Stream Ecologist Steven Wang, PhD, Water Chemist Kelly Kindscher, PhD, Restoration Ecologist Paul Liechti, MA, Compliance Specialist
remote sensing *geographic information systems* *watershed analyses*	Ed Martinko, PhD, Program Director Kevin Price, PhD, RS/GIS Director Stephen Egbert, PhD, RS/GIS Senior Scientist Dietrich Kastens, MA, RS/GIS Specialist John Lomas, RS/GIS Analyst Jennifer Kastens, MA, Graphics Specialist
environmental engineering *water chemistry and treatment* *environmental microbiology*	Steve Randtke, PhD, Environmental Engineer David Graham, PhD, Bioengineer
The Masters Dredging Company, Inc. Lawrence, KS *reservoir and river dredging* *aquatic vegetation control*	David Penny, ME, President and Design/Operation Specialist
Strategic Weather Services, Inc. Philadelphia, PA *meteorological data bases* *longer-term weather prediction* *weather/action plan coordination*	Fred Fox, President Steve Beck, CEO Rob Luca, VP and Application Specialist
Subject Reservoir *participation in all phases*	Local Personnel

TERRESTRIAL GREENNESS RELATED TO WEATHER PARAMETERS AS INDICATORS OF RESERVOIR CONDITIONS

Greenness and Vegetation Phenologic Metrics

Greenness is a generic term used to describe the condition of vegetation as observed from earth observation satellites that look at earth objects in discrete portions of the light spectrum known as spectral bands. There are many measures of satellite-derived greenness, some consisting of a single band (e.g., the green band or the near-infrared band) and others consisting of ratios of bands. The most commonly used and accepted greenness ratio is the normalized difference vegetation index (NDVI) which is an adjusted ratio of the near-infrared band and the red band. High values of NDVI indicate vigorously growing vegetation, while low values indicate areas of sparse vegetation or no vegetation at all. These values have been found to be strongly correlated to vegetation measurements such as biomass and leaf area index.

Plant phenology refers to the climate-related growth and development stages of plants. Because the phenologies or growth calendars of various plants and assemblages of plants differ from each other, there are corresponding differences in temporal patterns of greenness in the landscape. For example, winter wheat, which is planted in the fall, greens up briefly in late fall and the above-ground biomass then dies back over the winter months. In the spring it greens up early, ripens in May and June, and is harvested in late June or early July. Corn, on the other hand, is planted in April, greens up in May, reaches its peak in July, senesces in August, and is harvested in September. Because of these differences in temporal patterns, it is possible to use a time series of NDVI images over an entire year to separate wheat and corn, as well as other crops. Likewise, cool season grasses can be separated from warm season grasses, forested areas from grassland, and so on.

Time-series NDVI images can be harnessed to measure and evaluate the phenological progress of vegetation through a series of vegetation phenologic metrics (VPM). As the term implies, vegetation phenologic metrics are specific measurements of the development and condition over time based on satellite-derived greenness values (i.e., NDVI). These were initially developed by researchers at the USGS EROS Data Center in Sioux Falls, South Dakota and have been refined by scientists at the Kansas Applied Remote Sensing Program working with TerraMetrics, Inc. The set of key VPMs includes the following measures:

Temporal Metrics	Time of onset of greenness Duration of greenness	Time of end of greenness Time of maximum greenness
NDVI-Value Metrics	Value of onset of greenness Value of maximum NDVI	Value of end of greenness Range of NDVI
Derived Metrics	Accumulated NDVI Rate of senescence	Rate of green up Mean daily NDVI

VPMS can also be viewed graphically as follows:

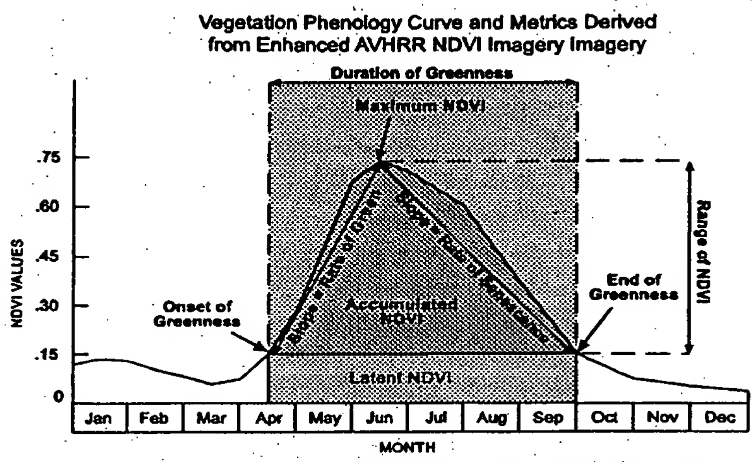


Figure 2. Diagram of a twelve-month NDVI temporal response for vegetation typical of the Great Plains. Greenness metrics that characterize vegetation phenology are illustrated on the curve to show the relationship between NDVI and time (After Tieszen et al., 1997).

In addition to the standard set of VPMs, it is possible to derive numerous additional measurements. For example, the mean onset of greenness or the variation in the onset of greenness (i.e., the standard deviation) for an area such as a watershed, county, or crop reporting district, can be calculated. Such derived measurements provide summary information over a defined spatial extent that may help in analyzing underlying ecosystem (or agro-ecosystem) processes.

Hypotheses about the Relationship of VPM Values to the Development of Taste and Odor Problems in Reservoirs

Although the relationships between VPMs and development of taste and odor problems are still being developed at this point, there are three general groups of hypotheses that can be formed.

Early season greenness. Inasmuch as chemical agricultural fertilizers are applied heavily in the spring, one contributor to aquatic vegetation growth and, consequently, taste and odor problems, might be heavy runoff of fertilizers into rivers and streams that feed reservoirs. Earlier than normal onset of greenness in agricultural areas might mean that crops have begun to develop earlier than normal compared to grasses, trees, and shrubs that ordinarily serve as buffers to absorb fertilizer runoff. In such a scenario, more chemical fertilizers than normal might feed into aquatic systems. On the other hand, later than normal onset might indicate a situation where fields have been planted late but where fertilizers were applied prior to planting. This situation might also permit heavier than normal fertilizer runoff into streams, since there are no crop roots to take them up or hold them.

In both these situations, the indicator greenness measures might simply be the date of onset of greenness or the rate of greenup. Or, it may be a derived measure such as the standard deviation of date of onset or rate of greenup within a watershed.

Terrestrial vegetation condition as a surrogate for reservoir vegetation condition. In this scenario, terrestrial and aquatic vegetation can be viewed as being independent from each other but responding to the same environmental inputs, primarily climatic in nature. Relevant climate conditions would be temperature patterns and related measures such as growing degree days. It is not necessary to establish causal links between terrestrial and aquatic vegetation, but to use measures of terrestrial vegetation greenness as surrogates for aquatic vegetation development. Measures of terrestrial greenness that might be expected to relate to high growth of aquatic vegetation might include high peak greenness values, a prolonged duration of greenness, and high accumulated greenness over a growing season.

Terrestrial biomass as a nutrient source. This relationship is based on the fact that decomposing vegetation from the current year's growth becomes dissolved organic matter that enters the aquatic system and becomes a nutrient source for the following year's aquatic vegetation. Indicator greenness values would be those that indicate a large crop of above-ground biomass, including total accumulated greenness over the growing season, duration of greenness, and high peak greenness.

Developments in Remote Sensing Technology and Implications for this Reservoir Work

In ideal circumstances, we would use satellite-derived greenness measures in conjunction with satellite imagery of reservoirs for research into the causes and prediction of taste and odor and other problems in reservoirs. In particular, we could be interested in examining water clarity and algal biomass. However, the current generation of remote sensing instruments is not optimized to provide adequate data for most inland water bodies. Instruments such as Landsat Thematic Mapper and SPOT have relatively high spatial resolution (30 and 20 meters, respectively, in multispectral mode), but do not have the narrow bandwidths in the blue and green wavebands that are optimized for aquatic applications. Moreover, their repeat coverage is only every two to three weeks (assuming no cloud cover), making it difficult to construct a consistent, unbroken view of change over time. On the other hand, the few sensors that have had bandwidths optimized for aquatic applications (none of which are currently flying) have been coarse-scale wide-field sensors (pixels of 800 m to 1100 m) designed primarily for ocean applications. These resolutions make it difficult to examine most inland water bodies.

Coarse resolution, 1.1 km, is also an issue with AVHRR imagery that is used to create the current greenness products. For example, a 5000-acre reservoir would be covered by approximately 16 AVHRR pixels, assuming that the reservoir was square and that the pixels were perfectly aligned with the shoreline. In reality, most reservoirs extend into several narrow arms that may be only a few hundred meters wide. It is in these shallow arms that algae and rooted vegetation growth is most prolific. A single 1.1 km pixel centered on one of these arms would include only a small area of water and would be dominated by surrounding terrestrial land cover that would obscure the spectral response of the water, or of vegetation in the water.

This year, NASA plans to launch new sensors that will address several of these problems of spatial and spectral resolution. The MODIS sensor, to be launched on the EOS Terra platform, will have 36 bands, with resolutions ranging from 250 m to 1000 m, depending on band wavelength. MODIS will enable us calculate new, finer resolution terrestrial VPMs based on 250 m resolution NDVI images. A second sensor, EO Hyperion, is a 200 band hyperspectral instrument that will provide 30 m resolution, the same as the Landsat Thematic Mapper. Hyperion will be able to look at inland lakes and reservoirs directly and correlate water clarity and aquatic vegetation growth with terrestrial vegetation conditions as reflected in the VPMs.

Prepared by Steve Egbert, Ph.D. Senior Remote Sensing and Geographic Information Systems Specialist, University of Kansas and TerraMetrics, Inc., Lawrence, KS.

Re: **Response to *Requirement for Information under 37 CFR § 1.105***

For: **System, Method, and Computer Program Product for Weather and Terrestrial Vegetation-based Water Renovation and Management Forecasting**

Inventors: Beck et al.

Ref: 1481.0170000

From: F. Denoyelles and S. Egbert, Lawrence, Kansas

We have reviewed the request for additional information from the Examiner, and the following constitutes our response to what we understand to be two key elements of the request: 1), an understanding of the level of knowledge of those of ordinary skill in the claimed subject matter art of weather and terrestrial-based analyses of bodies of water; and 2), an elucidation of what parts of the application that represent new or unique underlying methodology(ies) versus the automation of data gathering and calculations used to perform a well-known methodology or slight variation thereof.

We concede that the following subject areas generally represent ordinary knowledge or methodologies available to professionals within their respective fields. Citations supporting these subject areas can be produced if necessary/needed, in addition to commonly-used and available college-level limnology, remote sensing, hydrology, and climatology textbooks..

- Forecasting runoff into lakes, reservoirs, and impoundments following precipitation events;
- Short-term prediction of reservoir water levels following precipitation events;
- Seasonal changes in reservoir conditions as a result of normal limnologic processes (e.g., lake turnover);
- Effects of transient and seasonal weather conditions upon reservoir conditions (i.e., changes in turbidity, temperature, nutrient concentrations);
- Relationships between stream and reservoir water quality parameters (e.g., phosphorus, nitrogen) and blue-green algae outbreaks in reservoirs;
- Relationships between stream and reservoir water quality parameters (e.g., phosphorus, nitrogen) and the occurrence of excessive and uncontrolled aquatic plant growth in reservoirs;

- Relationships between blue-green algae concentrations, occurrence of geosmin and MIB in reservoirs, and outbreaks of drinking water taste-and-odor events;

- Relationships between ratios created from red : near-infrared reflectance of vegetation (as measured by satellite-based remote sensing instruments) and seasonal and interannual watershed vegetation phenology;

- Creation of vegetation phenological metrics (VPMs) from the Normalized Difference Vegetation Index, iteslf created from recorded red and near-infrared reflectance values;

- Relationships between watershed greenness indices, as measured by satellite remotely sensed imagery, and in-stream (but not in-reservoir) water quality parameters;

We assert the uniqueness and originality of the following:

- Relationships between seasonal vegetation greenness, as measured by remote sensing instruments, and drinking water taste-and-odor events in lakes and reservoirs;

- Relationships between long-term forecasted weather conditions and predicted reservoir conditions;

- Prediction of future watershed vegetation greenness values from long-term forecasted weather conditions;

- Relationships between forecasted watershed greenness values and predicted reservoir conditions;

- The integration of remotely sensed greenness measures and long-term forecasted weather conditions for predicting reservoir conditions (water quality and quantity, or both) at a future date.

Based on a search of the relevant scientific literature and our knowledge of the applicable scientific fields, no citable scientific literature references specific to these five subjects listed above were found to exist..

RECEIVED
JUL 1 - 2005
Sterne, Kessler, Goldstein & Fox, P.L.L.C.

GMS
TAD
7/1/05

Steven Beck
60 Bertolet School Rd.
Spring City, Pa. 19475

June 29, 2005

Sterne, Kessler, Goldstein, Fox
1100 New York Ave.
Washington, D.C. 20005
Attn: Tim Doyle, Esq.

Dear Tim,
Please be advised that I have no documents or work products that relate to the patent. I'm sorry that I am unable to provide any information.

Sincerely,

Steven Beck

Stephen J. Randtke, Ph.D., P.E.
2712 Lockridge Drive
Lawrence, KS 66047
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July 8, 2005

RECEIVED
JUL 11 2005
Sterne, Kessler, Goldstein & Fox, P.L.L.C. SMD SMD 7/11/05
TAD

Mr. Timothy A. Doyle
Sterne, Kessler, Goldstein, & Fox, PLLC
1100 New York Avenue, NW
Washington, DC 20005

Dear Mr. Doyle:

Re: Your letter dated June 17, 2005 regarding "System, Method, and Computer Program Product for Weather and Terrestrial Vegetation-Based Water Renovation and Management Forecasting" (Ref. 1481.0170000)

Thank you for informing me of the status of the patent application and for explaining the process and putting the Examiner's request in context. I regret that I was unable to respond more promptly.

I was involved in the preparation of the background section describing the invention, but I was not the primary author and did not directly draw upon any other documents. My primary expertise lies in the area of water quality and treatment. My contribution to the writing was based on my own knowledge and experience, which has been richly informed by my frequent collaborations with Dr. Frank (Jerry) deNoyelles, one of the other co-inventors, over the past 20 plus years.

It had long been evident to both of us that the quality of the water in a given stream or reservoir was governed primarily by the nature and state of the watershed and by the antecedent weather conditions. Thus, water quality could be explained, after the fact, by examining the characteristics of the watershed, rainfall records, etc.; but water quality could not be predicted because it was not possible to predict the weather or the condition of the watershed -- or so we thought until we began collaborating with Strategic Weather Services (SWS, as it was known at the time). We then realized that, if one could reliably forecast weather patterns, as they are able to do, it would be possible to forecast both the state of the watershed and the water quality that would result from the interaction between the weather and the watershed. Furthermore,

using an approach similar to the one they use to forecast weather patterns, the accuracy of such forecasts can be improved by drawing on existing water-quality and other databases. This is the essence of the invention.

Please feel free to contact me at (785) 864-2940 if I can be of further assistance. Best wishes for success in your efforts to secure a patent for this invention.

Sincerely,

Steve Randtke

Stephen J. Randtke, Ph.D., P.E.
Consulting Engineer

The Master's Dredging Company, Inc.
Dredging Contractors
P.O. Box 9, Lawrence, KS 66044
(913) 583-3200

Mr. Timothy A. Doyle
Sterne, Kessler, Goldstein, Fox
1100 New York Aven, NW
Washington, DC 20005

July 11, 2005

Re: U.S. Utility Patent Applications
Appl. No. 09/547,791; Filled: April 12, 2000
For: System, Method, and Computer Program Product for Weather and Terrestrial Vegetation-Based Water Renovation and Management Forecasting
Inventors: Beck *et al.*
Our Ref. 1481.017000

Dear Mr. Doyle:

I hope to answer some of the Examiner's request under 37 C.F.R. Paragraph 1.105. This process patent is unique in its very concept. I own a number of patents and have never seen a patent similar to this application.

Our contribution to this patent is ancillary in that we are involved in actual operations of renovating lakes and waterways by dredging and mechanical removal of invasive plants. We have worked in cooperation with Strategic Weather, now Planalytics, and the remote sensing groups of Terrametrics and KARS on several projects. It became clear that a computer model is necessary for forecasting the weather and vegetation for the restoration of reservoirs and waterways.

For instance, it would be catastrophic to release the water from a reservoir for repairs or dredging if there is no certainty that the weather is not going to refill the reservoir with water from rain. Future drought conditions could cause a major metropolitan area to run out of water from its water supply reservoir after repairs.

Likewise major infestations of invasive plants can destroy large aquatic systems. These disastrous events are often related to weather conditions and terrestrial and aquatic habitat. A good computer forecasting system could predict the likelihood of such an event. A mechanical or chemical eradication plan could be implemented well in advance to prevent the invasion from taking place. Such invasions generally result in mass killings of aquatic animals and native plants which take years to restore the aquatic system to its natural conditions.

We have a good website { www.theaquaticgroup.com } which shows some of the

breath of our experience in the renovation and restoration of lakes and waterways. With the variables of climatic conditions we often are at the mercy of weather.

Planalytics proposes, using their extraordinary long range weather predictions, to forecast future events which are identical to past weather events that lead to specific aquatic events. If past conditions produced specific events, then nearly identical future conditions will certainly lead to the same events. It is the standard scientific method. Given the same conditions, the natural realm always produces the same results. A predictive computer model would be invaluable to anticipate and to manage aquatic systems.

It will be hard for the Examiner to find comparable types of past patents to this application by Planalytics, Inc. No one to my knowledge has ever attempted to build a predictive computer system for the renovation and management of aquatic systems. Given Planalytics' success in predicting the weather and applying it to other weather-related events, it would certainly beneficial if they can predict future events for the aquatic systems which are definitely weather-related.

Sincerely,

David Penny
President

Timothy Doyle - Re: Response to request for Information (Beck et al.,Ref1481.017000

From: "Sam Campbell" <scamp@sunflower.com>
To: "Timothy Doyle" <TDOYLE@skgf.com>
Date: 7/19/2005 5:57 PM
Subject: Re: Response to request for Information (Beck et al.,Ref1481.017000

I have conferred with deNoyelles etal and confirm that I do not have any additional information.
Sam Campbell

> ----- Original Message -----
> **From:** Timothy Doyle
> **To:** scamp@sunflower.com
> **Sent:** Friday, July 15, 2005 5:01 PM
> **Subject:** Fwd: Response to request for Information (Beck et al.,Ref1481.017000
>
> Mr. Campbell:
>
> In our July 8, 2005, telephone conference, you mentioned that you had spoken with Professors deNoyelles and Egbert and that you did not believe that you had any additional information to contribute to this patent application beyond the information that they were planning to provide.
>
> Attached please find a message that was sent to me on their behalf with a two page document of the information that they are providing.
>
> Please review this information and confirm that you do not have any additional information.
>
> Thanks,
> Tim Doyle
>
> Timothy A. Doyle
> Sterne, Kessler, Goldstein & Fox P.L.L.C.
> 1100 New York Avenue, N.W.
> Washington, D.C. 20005
> tdoyle@skgf.com
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> Secretary: (202) 772-8819
> (Ms. Sandy Williams)
>
>